Bulletin 230 March, 1930

Growth Studies with Swine

by J. H. LONGWELL,
H. O. HENDERSON, and W. M. INSKO, Jr.

Pig Showing Typical Posterior Paralysis
Developed on Basal Ration No. 2

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*Growth Studies with Swine**

by J. H. LONGWELL, H. O. HENDERSON, and W. M. INSKO, Jr.†

THE EXPERIMENTS reported in this bulletin were undertaken with three objects in view: namely, to determine the effects of feeding butterfat; to determine the effects of feeding margarine fats and oils; and to determine the effects of feeding a basal ration free from the known sources of the fat-soluble growth vitamin upon the growth and development of pigs. When this experiment was started in 1923 very little had been published concerning the existence of an antirachitic vitamin—vitamin D—which is also fat-soluble. Although Mellanby *(1921)* and McCollum and coworkers *(1922)* had presented evidence of the existence of a calcium depositing substance in cod-liver oil and butterfat, and of its resistence to oxidation which destroyed vitamin A, very little confirmatory evidence had been published. Later workers confirmed the existence of such a factor and so, in 1926, a new object was added to the experiment: namely, to determine the effect of adding butter and vegetable margarine to a known rachitic ration upon the growth and development of pigs.

This bulletin is a preliminary report on studies begun in 1923 to determine the effect on the growth of pigs of adding butter, oleomargarine, or vegetable margarine to a basal ration deficient in the fat-soluble, growth-promoting vitamin. Up to the present time the effects of the fats upon growth have been measured by the rate and economy of gains made by the pigs, and by observation of the abnormal symptoms exhibited by those pigs suffering from dietary deficiencies. In only one case was a post-mortem examination conducted and a physical examination made of the bones.

Continued investigations on this project will include, in addition to the observations being made, a complete history of the fats used; a study of the ability of the fats to bring about recovery of pigs suffering from avitaminosis; autopsies of all pigs tested; physical examination of bones, including photographic records, hardness tests, and histological examinations; and chemical studies, particularly of the mineral content of the bones.

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†Mr. Insko resigned July, 1927.

The experimental work for 1923, 1925, and 1926 was under the direction of E. C. Stillwell[1] and Warren Gifford.[2] It was supervised by E. A. Livesay[3] and E. L. Anthony.[4] W. N. McClung, herdsman, had charge of the feeding and weighing of the animals. The oxygenated cod-liver oil used was prepared by R. B. Dustman.[5] All feed analyses were made by the department of agricultural chemistry of the Agricultural Experiment Station.

GENERAL PLAN OF THE EXPERIMENTS

All experiments reported in this bulletin were conducted in dry-lot during the summers of 1923, 1925, 1926, and 1927 by the departments of animal husbandry and dairy husbandry of the West Virginia University on the animal husbandry farm.

The pigs were fed in clean metal troughs in the central hog barn and watered in the same troughs, which were thoroughly cleaned after each feeding. The animals had access to lots having concrete floors, except in 1923, when the runways were of earth. As the runways were in the open, the pigs were exposed to the sun, except in 1927, when the pigs were confined to the barn. The pens were kept as clean as possible in order that the experiments might be relatively free from any disturbing influences of unsanitary surroundings.

Two litters were used in each trial, the pigs of each litter being divided equally among the lots. The pigs were weaned at eight weeks of age and were started immediately on the trial, except in 1925, when the pigs were ten weeks old when started. All of the pigs first were treated for internal parasites, then sprayed with crude oil to kill external parasites. All pigs were weighed individually at intervals of 14 days.

In the original plan of the experiment the basal ration (No. 1) consisted of 5 parts of white corn, 4 parts of whole oats, and 1 part of a mixture of 3 parts of tankage and 1 part of linseed oilmeal. To this basal ration a mineral mixture was added at the rate of one ounce per day for each 100 pounds of live weight. The mineral mixture given in 1923 and 1925 consisted of 5 pounds of acid phosphate, 5 pounds of steamed bone meal, and 1 pound of salt. This mixture was altered in 1926 to 5 pounds of acid phosphate, 5 pounds of steamed bone meal, 5 pounds of ground limestone, and 2 pounds of salt.

As far as was known at the beginning of the experiment this basal ration was free from the fat-soluble growth vitamin. Steenbock and Boutwell *(1920)* showed that white corn contains no appreciable amount of the fat-soluble growth vitamin, although yellow corn contains enough of this substance to allow growth at a normal rate. These experiments have been confirmed with hogs by Livesay and

[1]Now at the Ontario Agricultural College.
[2]Now at the University of Missouri.
[3]Head of the department of animal husbandry.
[4]Then head of the department of dairy husbandry; now at Michigan State College.
[5]Head of the department of agricultural chemistry.

Stillwell *(1927)* of this Station. McCollum and Simmonds *(1925)* state that the grains (wheat, maize, and oats) are deficient in vitamin A.

In 1926 the same basal ration was used as a check ration, and a new basal ration was included, composed of 300 pounds of white corn, 100 pounds of buckwheat middlings, and 20 pounds of tankage. This Station had found that this ration promoted rapid growth for a limited time but was quite deficient in vitamins A and D.

The rations were fed at the rate of 4 pounds per 100 pounds of live weight in 1923. In 1925 and 1926, 5 pounds per 100 pounds of live weight were fed per day, and in 1927, 4½ pounds per 100 pounds of live weight.

All experiments were continued approximately 100 days. Photographs of all lots were taken at the end of the feeding period.

Comparison of Butter and Oleomargarine for Growing Pigs

During the feeding trial of 1923 butter and oleomargarine were compared when added to the basal ration of white corn, oats, tankage, and linseed oilmeal, which was fed to Lot I. One ounce of butter for each 100 pounds of live weight was added to the basal ration of Lot II. The same amount of oleomargarine was added to the basal ration of Lot III.

The butter fed was a good grade of creamery butter that had been carefully stored to avoid aeration. No history of the feeds used in producing this butter was available. The oleomargarine,[7] of the best grades, was composed of oleo oil, neutral oil, cottonseed oil, and milk. Oleo oil is produced from beef fat, more especially the caul and ruffle fat. Neutral oil is made from the leaf fat of the hog. The fats are emulsified in the milk, and after absorbing the milk flavor the product is chilled with water and worked in the same manner as butter, salt being added.

Osborne and Mendel *(1915)* in experiments performed with rats found that when lard was the sole source of fat the animals grew normally for about three months. If the same ration was continued there was a cessation of growth, decline in body weight, and ultimate death. If, however, butter or beef fat was added to the ration, normal growth was continued. The recovery when beef fat was fed after decline was not so marked as when butterfat was fed. The growth-promoting factors were found to be concentrated in the oil of the fat. Halliburton and Drummond *(1917)* as the result of a series of experiments performed with rats concluded: (1) The fat-soluble growth substance is present in beef fat and oleo oil and in margarines prepared on such a basis. These margarines are nutritively the equivalent of butter. (2) Cocoanut oil, cottonseed oil, arachis-oil, and hydrogenated vegetable oils contain little or none of this accessory sub-

[7] A number of articles have been written concerning the relative food value of butter and margarine. The chief difficulty encountered in a study of these articles is the apparent looseness of application of the terms margarine and oleomargarine. To avoid confusion the authors have introduced the trials with oleomargarine and vegetable oil margarine under separate sections. The first section of this bulletin is concerned only with oleomargarine, or margarine containing animal fats.

stance; hence margarines prepared with a basis of these fats do not have a nutritive value equal to that of butter. (3) Nut butters prepared from crushed nuts and vegetable fats similarly are not equal to butter.

In 1923, 15 Poland-China pigs were selected from two litters for the present experiment. One litter contained 6 pigs; the other, 9 pigs. Two pigs were selected from the former and three from the latter for each lot. The three lots were given a preliminary feed of fourteen days on the basal ration, then weighed and started on the experiment.

Lot I received the original basal ration No. 1 and mineral mixture; Lot II, the basal ration, mineral mixture, and two ounces of butter per day for each 100 pounds of live weight; and Lot III, the basal ration, mineral mixture, and two ounces of oleomargarine per day for each 100 pounds of live weight.

TABLE 1.—*Individual and Total Lot Weights by Two-week Periods of Pigs in Three Lots in 1923*

Lots	Weights at Two-week Intervals *(Pounds)*							
	July 19	Aug 2	Aug. 16	Aug. 30	Sept. 13	Sept. 27	Oct. 11	Oct. 25
I								
No. 1	44	52	60	74	87	103	119	137
No. 2	48	54	61	73	85	101	117	139
No. 3	28	31	39	46	58	70	83	91
No. 4	26	27	34	41	50	62	72	84
No. 5	30	33	34	44	50	64	76	92
Total	176	197	228	278	330	400	467	534
II								
No. 1	37	47	51	64	75	94	112	129
No. 2	50	55	67	81	100	121	138	153
No. 3	32	37	44	53	63	78	94	113
No. 4	30	35	39	48	59	75	90	107
No. 5	26	28	33	42	50	66	80	93
Total	175	202	234	288	347	434	514	593
III								
No. 1	44	49	58	70	77	95	112	126
No. 2	48	58	62	74	85	105	122	139
No. 3	28	34	37	43	50	60	68	84
No. 4	25	32	36	47	56	69	82	93
No. 5	32	32	41	49	62	79	92	108
Total	177	205	234	283	330	408	476	550

The increase in weight as found in Lots II and III was not sufficient to pay for the butter and oleomargarine used in feeding. However, as shown in Table 2, the total feed for each 100 pounds of gain was less in the case of the butter lot than in the oleomargarine and check lots. The lot fed oleomargarine required less feed for each 100 pounds of gain than the check lot. The total feed for each 100 pounds of gain was 396 pounds for Lot I, fed the basal ration; 364 pounds for Lot II, receiving the basal ration and butter, and 385 pounds for Lot III, fed the basal ration and oleomargarine.

The total gains of the three lots were 358 pounds for Lot I, 418 pounds for Lot II, and 373 pounds for Lot III. While Lots II and III showed slightly greater gains than Lot I, such gains can be attributed largely to the energy value of the fats added to the rations.

Since there were but 5 pigs per lot, little importance can be attached to the differences in rate and economy of gains between the various lots.

The analysis of feeds fed is shown in Table 3.

Figure 1 shows that the gains of the lots were uniform throughout the feeding period. This graph is based on the total lot weights given in Table 1. The butter lot gained more than either of the other lots. However, the increase over the oleomargarine lot was only 43 pounds, and the oleomargarine lot weighed only 16 pounds more than the check lot at the final weighing. Even though there was a gain

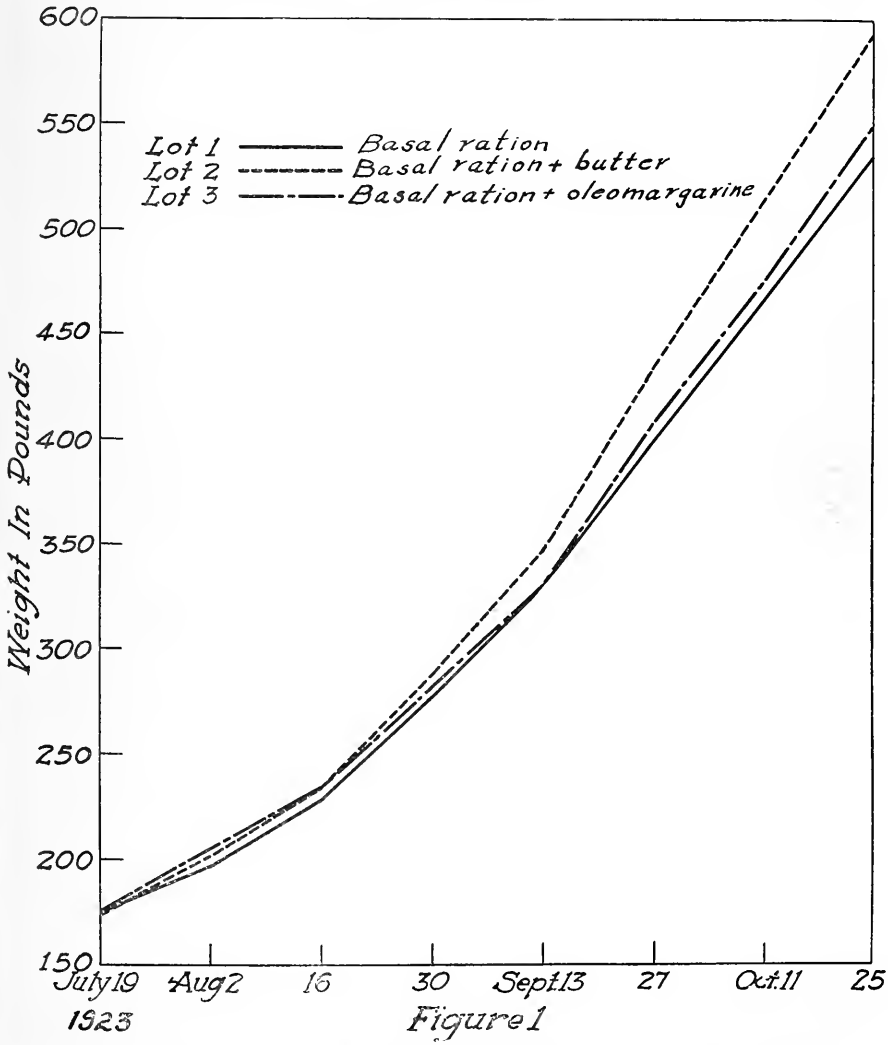


FIGURE 1.—Growth Curves Based on Total Lot Weights as Given in Table 1

over the check ration in each of the lots to which fat was added, the increase was little more than would be expected to result from the energy contained in the fats added to these rations.

TABLE 2.—*Feed and Weight Records of Pigs in Three Lots in 1923*

Item	Rations Fed		
	Lot I	Lot II	Lot III
	Basal Ration* and Mineral Mixture†	Basal Ration, Mineral Mixture, and 1 oz. Butter per 100 Pounds Daily	Basal Ration, Mineral Mixture, and 1 oz. Oleomargarine per 100 Pounds Daily
Number of days on feed	98	98	98
Number of pigs per lot.....	5	5	5
Total gain per lot *(pounds)*	358	418	373
Average initial weight per pig	35.2	35.0	35.4
Average final weight per pig..	106.8	118.6	110.0
Average daily gain per pig...	0.73	0.85	0.76
Total feed per 100 pounds gain	396.1	364.0	385.2

*Basal ration—white corn, 5 parts; oats, 4 parts; tankage (3) and linseed oilmeal (1), 1 part.

†Mineral mixture—acid phospate, 5 pounds; steamed bone meal, 5 pounds; and salt, 1 pound.

FIGURE 2.—Lot I, fed basal ration and mineral mixture (1923)

TABLE 3.—*Analysis of Feeds Fed in 1923*

Feed	Nutrients (Percent)					
	Water	Ash	Crude Protein	Carbohydrates		Fat
				Fiber	N-free Extract	
White Corn ...	10.41	1.41	9.69	1.96	72.78	3.84
Oats*	9.20	3.50	12.40	10.96	59.60	4.40
Tankage	9.50	20.17	58.51	1.46	4.80	5.56
Linseed oilmeal	7.06	5.18	31.47	14.18	35.50	6.61

*Analysis of oats from Henry and Morrison, *Feeds and Feeding.*

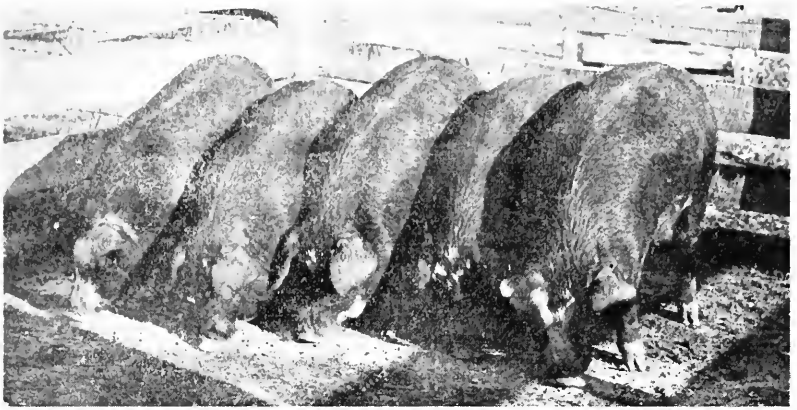


FIGURE 3.—Lot II, fed basal ration, mineral mixture, and butter (1923)

Figures 2, 3, and 4 show the appearance of the lots at the end of the feeding period. As may be observed, Lot II had slightly more finish and was somewhat smoother as well as lightly heavier. Lot III also was smoothly covered and carried more finish than Lot I. Lot I, which received the basal ration, carried less finish than the other two lots although all lots were uniform in weight.

In conclusion it may be said that when butter or oleomargarine was added to a basal ration of white corn, oats, linseed oilmeal, and tankage there was a little increase in weight, due to the added fat or added fat-soluble growth vitamin. The increase was slight, however, and was in favor of the lot receiving butter. This result with pigs substantiates the work with rats as done by Osborne and Mendel *(1915)* and by Halliburton and Drummond *(1917)*.

FIGURE 4.—Lot III, fed basal ration, mineral mixture, and oleomargarine (1923)

Comparison of Butter and Vegetable Margarine (First Trial)

During the feeding trials of 1925 and 1926 butter and vegetable margarine were compared when added to the basal ration. In 1925 the basal ration was the same as in 1923.

Lot I received the basal ration and mineral mixture; Lot II received the basal ration, mineral mixture, and 2 ounces of butter for each 100 pounds of live weight daily; and Lot III received the basal ration, mineral mixture, and 2 ounces of vegetable margarine[8] for each one hundred pounds of live weight daily.

TABLE 4.—*Individual and Total Lot Weights by Two-week Periods of Pigs in Three Lots in 1925*

Lots	Weights at Two-week Intervals *(Pounds)*							
	June 25	July 8	July 22	Aug. 5	Aug. 19	Sept. 2	Sept. 16	Sept. 30
I								
No. 1	50	58	70	89	100	111	146	164
No. 2	40	45	60	73	90	120	134	143
No. 3	46	58	66	84	98	114	128	146
No. 4	46	58	66	89	92	104	124	144
No. 5	53	66	78	91	110	130	154	170
Total	235	285	340	426	490	579	686	770
II								
No. 1	48	61	76	94	112	135	160	192
No. 2	44	55	64	75	91	108	130	144
No. 3	52	64	76	92	112	132	160	180
No. 4	40	50	57	72	87	104	130	145
No. 5	48	64	78	93	113	133	160	185
Total	232	294	351	427	516	612	740	846
III								
No. 1	51	65	76	91	105	123	148	166
No. 2	43	50	61	73	90	106	126	150
No. 3	42	50	56	68	70	92	110	131
No. 4	50	64	75	98	116	133	155	173
No. 5	49	66	78	94	114	136	165	182
Total	235	295	346	424	505	590	704	802

The work of Halliburton and Drummond *(1917)* showed that margarines prepared with a basis of cocoanut oil, cottonseed oil, and hydrogenated vegetable oils are not equal in nutritive value to butter.

Sixteen pigs from two litters were used in the 1926 experiment. Four pigs were placed in each lot. As seen in Figure 6 and Table 7, there was very little variation in the weights of the four lots at the beginning of the experiment. One pig in Lot II died before the end of the feeding trial.

In the trial in 1925 as shown in Table 4, Lot II, which received butter in addition to the basal ration, gained more than either Lot I or Lot III. Lot III, receiving the vegetable margarine in addition to the basal ration, gained more than Lot I, which received only the basal ration.

[8]Nut or vegetable margarine is made in much the same manner as oleomargarine. The ingredients are cocoanut fat, cottonseed, and other vegetable oils. These fats are emulsified with milk. They are then chilled with cold water and worked in the same manner as oleomargarine. Salt is added.

The curves in Figure 5 show that the gains in all lots were uniform and, considering the greater energy intake in Lots II and III, practically equal.

As shown in Table 5, the lot receiving the butter required the smallest number of pounds of feed for each 100 pounds of gain. This lot required 387.3 pounds, while Lot III required 409.7 pounds, and Lot 1, 414.6 pounds. As with the 1923 trial, the differences in rate and economy of gains may be credited principally to the greater energy intake in the lots receiving fat. The analysis of feeds fed in 1925 is given in Table 6.

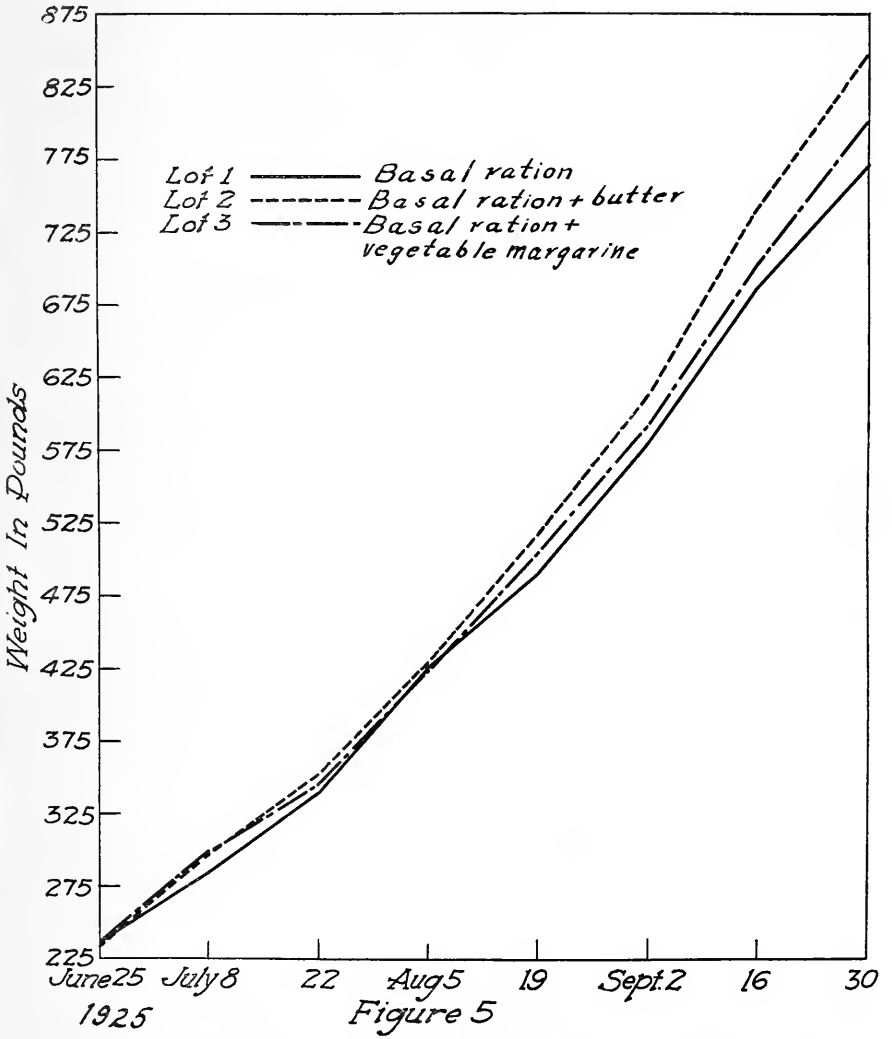


FIGURE 5.—Growth Curves Based on Total Lot Weights as Given in Table 4

Comparison of Butter and Vegetable Margarine (Second Trial)

Since the trials of 1923 and 1925 had shown only slight differences in the rate of gains and in the economy of gains between the lots fed the check rations and those fed the check rations plus butter, or plus oleomargarine, or plus vegetable margarine, it was decided to substitute a new basal ration in 1926. During the winter feeding trials reported by Livesay and Stillwell *(1926)* pigs receiving a ration of white corn, buckwheat middlings, and tankage developed rickets, going down on the seventieth day of the feeding trial. These pigs, however, made good gains and quickly recovered when fed either untreated or oxygenated cod-liver oil. The treated oil was prepared according to the directions of McCollum and Simmonds *(1925)*.

With the purpose of obtaining data on the existence of the antirachitic vitamin (vitamin D) in butter and vegetable margarine, the winter basal ration was substituted for the basal ration used in the two previous summers. This new ration (Basal Ration No. 2) was composed of white corn, 300 pounds; buckwheat middlings, 100 pounds; tankage, 20 pounds; and a mineral mixture composed of 5 pounds of steamed bonemeal, 5 pounds of ground limestone, 5 pounds of acid phosphate, and 2 pounds of salt.

Lot I received the original basal ration of white corn, oats, linseed oilmeal, and tankage, plus the mineral mixture. Lot II received the new basal ration and the mineral mixture. Lot III received the new basal ration, mineral mixture, and 2 ounces of butter for each 100 pounds of live weight daily. Lot IV received the new basal

TABLE 5.—*Feed and Weight Records of Pigs in Three Lots in 1925*

Item	Rations Fed		
	Lot I	Lot II	Lot III
	Basal Ration* and Mineral Mixture	Basal Ration, Mineral Mixture, and 2 oz. Butter per 100 Pounds Daily	Basal Ration, Mineral Mixture, and 2 oz. Vegetable Margarine per 100 Pounds Daily
Numbers of days on feed.....	98	98	98
Number of pigs per lot.....	5	5	5
Total gain per lot *(pounds)*....	535	614	587
Average initial weight per pig	47.0	46.4	47.0
Average final weight per pig..	154.0	169.2	160.4
Average gain per pig	107.0	122.8	113.4
Average daily gain per pig...	1.09	1.25	1.16
Total feed per 100 pounds gain	414.6	387.3	409.7

*Basal ration—white corn, 5 parts; oats, 4 parts; tankage (3) and linseed oilmeal (1), 1 part.

TABLE 6.—*Analysis of Feeds Fed in 1925*

Feed	Nutrients (Percent)					
	Water	Ash	Crude Protein	Carbohydrates		Fat
				Fiber	N-free Extract	
White corn	13.21	1.25	8.33	2.49	71.79	2.93
Oats	8.36	3.27	10.09	11.17	62.28	4.83
Tankage	7.71	21.60	59.36	1.20	2.33	7.80
Linseed oilmeal .	8.83	5.31	34.10	8.44	37.25	6.07

ration, mineral mixture, and 2 ounces of vegetable margarine for each 100 pounds of live weight daily.

Since pig No. 3 in Lot II died on the 89th day of the feeding trial, the average consumption of feed for each 100 pounds of gain was calculated on the nearest weigh day. This was the 84th day of the trial. As shown in Table 8, Lot I consumed 340 pounds per 100 pounds of gain; Lot II, 334 pounds; Lot III, 330 pounds; and Lot IV, 340 pounds. The differences in rate and economy of gains are not important. The weights for the succeeding weigh periods are given in Table 7.

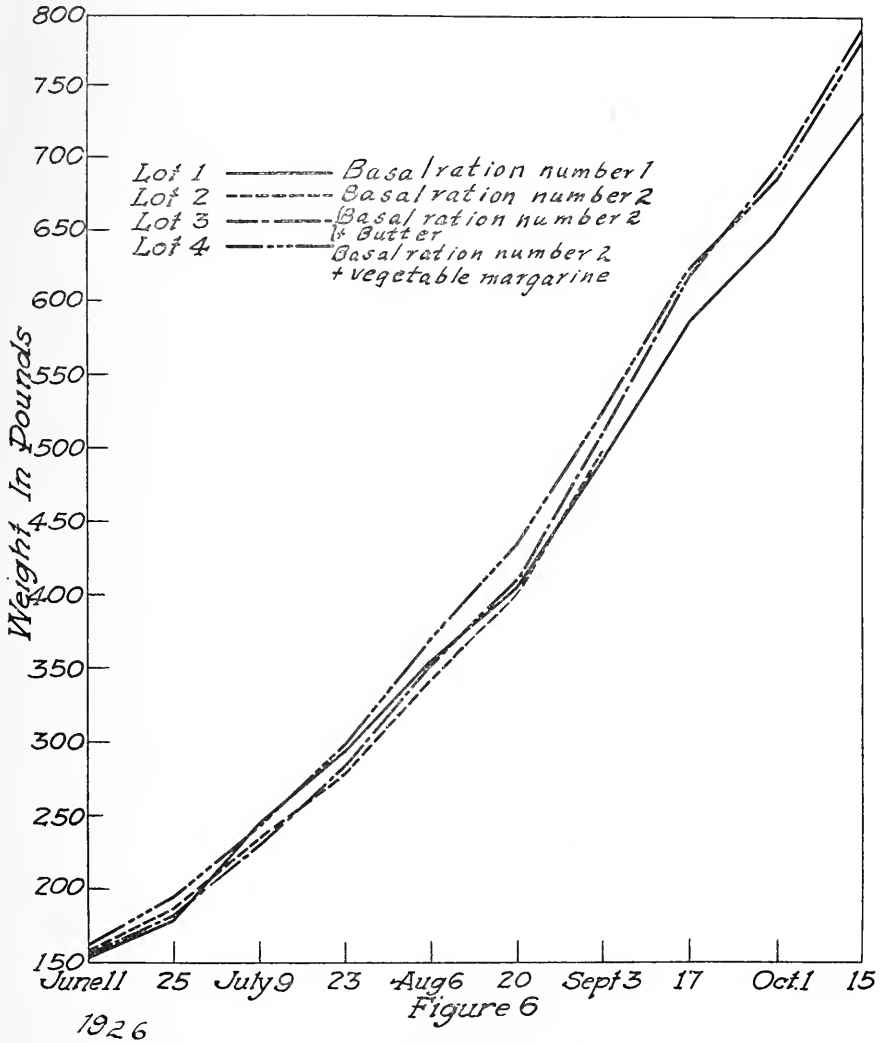


FIGURE 6.—Growth Curves Based on Total Lot Weights as Given in Table 7

FIGURE 7.—Lot I, Fed Basal Ration No. 1 and Mineral Mixture (1926)

FIGURE 8.—Lot II, Fed Basal Ration No. 2 and Mineral Mixture (1926)

TABLE 7.—*Individual and Total Lot Weights by Two-week Periods of Pigs in Four Lots in 1926*

Lots	Weights at Two-week Intervals *(Pounds)*									
	June 11	June 25	July 9	July 23	Aug. 6	Aug. 20	Sept. 3	Sept. 17	Oct. 1	Oct. 15
I										
No. 1	44	52	66	80	96	108	158	137	180	190
No. 2	48	54	68	80	96	110	150	132	166	186
No. 3	38	46	60	74	88	102	141	119	154	178
No. 4	24	26	52	60	74	84	139	104	150	176
Total	154	178	246	294	354	404	492	588	650	730
II										
No. 1	52	58	68	80	94	112	137	172	186	210
No. 2	32	38	52	62	76	94	116	128	158	180
No. 3	40	46	60	72	90	104	129	died September 8		
No. 4	34	44	54	66	82	90	115	140	146	168
Total	158	186	234	280	342	400	497	440	490	554
III										
No. 1	54	58	76	90	108	124	158	181	204	230
No. 2	38	44	52	68	84	98	118	145	168	188
No. 3	30	38	48	58	76	92	114	140	156	184
No. 4	34	42	54	68	84	96	122	154	166	186
Total	156	182	230	284	352	410	510	620	694	788
IV										
No. 1	52	56	60	72	102	84	118	158	172	200
No. 2	46	56	68	82	122	100	152	172	196	224
No. 3	30	40	52	66	98	82	116	130	144	160
No. 4	34	44	64	80	114	104	140	162	174	200
Total	162	196	244	300	370	436	526	622	686	784

FIGURE 9.—Lot III, Fed Basal Ration No. 2, Mineral Mixture, and Butter (1926)

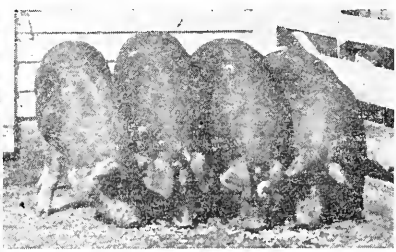


FIGURE 10.—Lot IV, Fed Basal Ration No. 2, Mineral Mixture, and Vegetable Margarine (1926)

The analysis of feeds fed in 1926 is given in Table 9.

The lots at the final weigh period are shown in Figures 7 to 10 inclusive. Lots III and IV were more uniform and smoother than Lots I and II. However, all lots were in good condition and brought an excellent price on the market. Pig No. 3 of Lot II was given a post-mortem examination with the results as shown in Figures 12 to 16, inclusive.

FIGURE 11.—A pig from Lot II showing posterior paralysis (1926)

As shown in Table 8, two pigs from Lot II and two pigs from Lot IV developed rickets, going down on the 86th day. Since rickets had developed in the lots receiving the new basal ration during the preceding winter feeding trials, this development was expected in Lot II. On the 81st day, signs of the approaching trouble were first noticed in the two lots. The symptoms were nervousness, drooping ears, failure to eat, reddening of eyes, and wobbly gait. Although the eye trouble was not uniform, in one case it approached blindness. On the 86th day two pigs of each lot went down, unable to rise.

The pigs of Lot II were given untreated cod-liver oil and those of Lot IV oxygenated cod-liver oil at the rate of 25 c. c. for each 100 pounds of live weight daily. One pig of Lot II failed to recover, dying on the 89th day. The other pigs recovered; the three which had collapsed were on their feet fourteen days after they went down and were in good condition twenty-six days after the treatment began.

Although post-mortem examination showed the lack of calcification of the ribs and femur, as well as vertebral fracture, the external condition was most noticeable as posterior paralysis. As shown in Figure 11 and on the cover, the animal lost control of the hind quarters and was unable to stand. The direct cause of this trouble was the fracture of the fifth vertebra of the loin or lumbar region. This vertebra pressed upon the spinal cord (Figures 12 to 14), thus causing deadening or paralysis of the nerves controlling the movement of the rear portion of the body.

Post-mortem examination showed that the ribs were beaded. The femurs showed porous areas, and both ribs and femurs showed areas

TABLE 8.—*Feed and Weight Records of Pigs in Four Lots in 1926*

Item	Rations Fed			
	Lot I	Lot II	Lot III	Lot IV
	Basal Ration No. 1* and Mineral Mixture	Basal Ration No. 2† and Mineral Mixture	Basal Ration No. 2,† Mineral Mixture, and 2 oz. of Butter per 100 Pounds Daily	Basal Ration No. 2,† Mineral Mixture, and 2 oz. of Vegetable Margarine per 100 Pounds Daily
Number of days on feed	84	84	84	84
Number of pigs per lot	4	4	4	4
Total gain per lot *(pounds)*	338	339	354	364
Initial weight per pig	38.5	39.5	39.0	40.5
Final weight per pig	123.0	124.2	127.5	131.5
Total gain per pig	84.4	84.7	88.5	91
Daily gain per pig	1.00	1.00	1.05	1.08
Total feed per 100 pounds gain	340.0	334.0	330.0	340.0
Number of pigs going down	0	2	0	2
Days on feed before developing rickets	....	86‡	....	86‡
Pigs dying	0	1	0	0

*Basal ration No. 1—white corn, 5 parts; oats, 4 parts; tankage (3) and linseed oilmeal (1), 1 part.
†Basal ration No. 2—white corn, 300 pounds; buckwheat middlings, 100 pounds; tankage, 20 pounds.
‡Two pigs in Lot II and two in Lot IV went off feed on the 86th day and one pig in Lot II died on the 89th day; hence feed and weight records are calculated to the nearest weigh day, the 84th day.

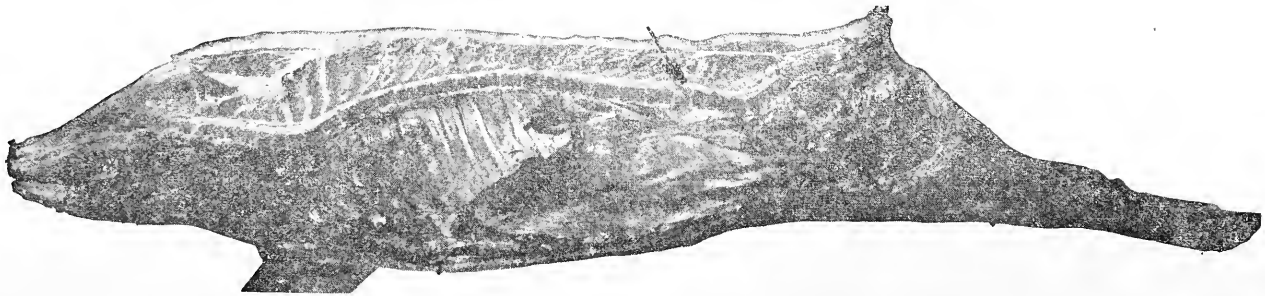


FIGURE 12.—One Side of the Pig Shown in Figure 11. The Fracture of the Lumbar Vertebra and the Beading of the Ribs are Very Distinct

of fresh calcification at the tips. (Figures 15 and 16). This examination would lead to the belief that the pathological condition was due to the lack of vitamin D, since there was present in the mineral mixture sufficient bone-producing substance, which apparently was not assimilated.

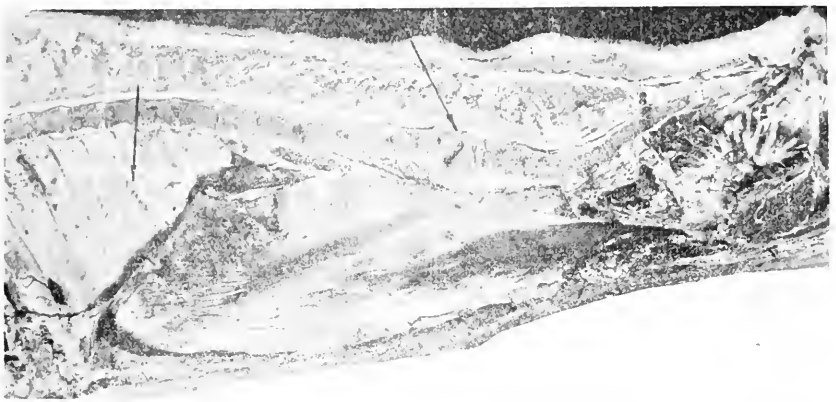


FIGURE 13.—A portion of the side shown in the previous figure. Note the fracture of the lumbar vertebra and the beading of the ribs due to the failure to assimilate the mineral of the ration

TABLE 9.—*Analysis of Feeds Fed in 1926*

Feed	Nutrients (Percent)					
	Water	Ash	Carbohydrates		N-free Extract	Fat
			Crude Protein	Fiber		
White Corn	11.39	1.43	8.67	2.56	72.15	3.50
Oats	7.63	2.51	11.33	11.63	62.10	4.80
Tankage	7.61	20.23	50.45	2.09	12.40	7.31
Linseed oilmeal	8.31	4.57	33.65	9.38	28.53	5.58
Buckwheat middlings	9.73	2.84	22.98	6.07	53.18	5.20

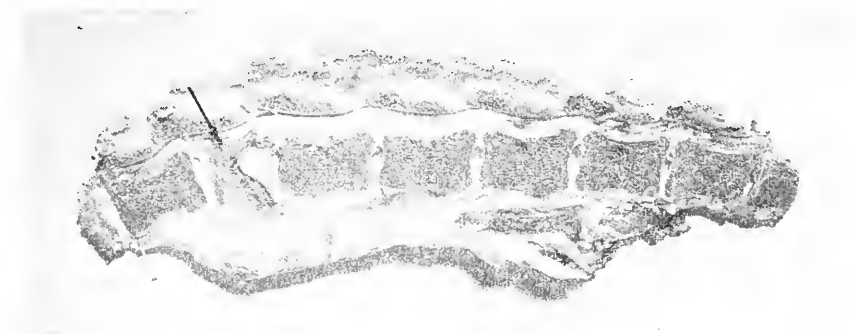


FIGURE 14.—The fractured lumbar vertebra causing posterior paralysis. The pig from which this backbone was taken had received a ration of white corn, buckwheat middlings, and tankage, with a mineral mixture

Since there was no evidence of lack of assimilation of bone-producing materials in Lot III, which received butter, it is apparent that over a period of 126 days there is present enough vitamin D in butter to prevent rickets. The basal ration consisting of white corn, buckwheat middlings, and tankage contained very little, if any, vitamin D, and therefore Lot II, receiving this ration, developed rickets. Lot IV, receiving vegetable margarine in addition to the basal ration, also developed rickets. This lot was returned to normal by the use of oxygenated cod-liver oil.

Lot I, receiving a ration of white corn, oats, linseed oilmeal, and tankage, did not develop rickets. This result supports previous work at this Station which indicates that oats in the ration will prevent rickets during a limited feeding period. This work is being continued to determine more definitely the anti-rachitic properties of whole oats.

Comparison of Butter, Oleomargarine, and Nut Margarine

Before 1927 no more than two of the fats in question had been compared at one time. In the trial for this year, therefore, all three were fed.

Conditions of feeding were similar to those in previous years except that all pigs were fed inside the barn and were not exposed to sunlight at any time during the trial.

FIGURE 15.—Sections of a femur from a pig affected with rickets. Note the areas of poor calcification

TABLE 10.—*Summary of Feed and Weight Records of Pigs in Four Lots in 1927*

Item	Division of Pigs			
	Lot I	Lot II	Lot III	Lot IV
Number of pigs	4	4	4	4
Total initial weight *(pounds)*	167	164	166	166
Total final weight	853	921	868	830
Total gain	686	757	702	664
Average initial weight	41.8	41.0	41.5	41.5
Average final weight	213.3	230.3	217.0	207.5
Average gain	171.5	189.3	175.5	166.0
Number of days on experiment	127	127	127	127
Average daily gain	1.35	1.49	1.38	1.30
Feed Consumed				
White corn *(pounds)*	1864.8	1864.0	1824.5	1738.5
Buckwheat middlings	621.6	621.4	608.2	579.5
Tankage	124.3	124.3	121.6	116.9
Lard	74.4			
Butter		89.6		
Oleomargarine			85.5	
Nut margarine				82.1
Mineral	87.2	89.6	85.5	82.1
Total	2772.3	2788.9	2725.3	2598.1
Feed consumed per 100 pounds gain				
White corn	271.80	246.20	259.90	261.80
Buckwheat middlings	90.6	82.1	86.6	87.3
Tankage	18.1	16.4	17.3	17.5
Lard	10.8			
Oleomargarine			12.2	
Nut margarine				12.4
Butter		11.6		
Mineral	12.7	11.6	12.2	12.4
Total	404.1	367.8	388.2	391.2
Pigs showing eye trouble, nervousness, and labored breathing	4	0	0	4
Pigs showing incoordination and paralysis	2	0	0	2
Pigs dying	0	0	0	1

The pigs in each lot received the same basal ration, consisting of 300 pounds of white corn, 100 pounds of buckwheat middlings, and 20 pounds of tankage. The pigs were weighed every two weeks and were fed this mixture at the rate of 4.5 pounds of feed for each 100 pounds of live weight, the daily amount remaining constant until the next weigh day. The pigs were fed twice daily. Toward the end of the experiment the pigs failed to clean up this amount of feed, so that the ration was reduced to 4 percent of the live weight. This was true in the case of the normal pigs as well as those showing symptoms of avitaminosis. All lots received a mineral mixture at the rate of 2 ounces for each 100 pounds of live weight daily.

Lot I, the check lot, received enough lard to maintain the energy intake on the same level as in the other lots. The lard used was high-quality open-kettle-rendered leaf lard. Work by Osborne and Mendel *(1915)* indicates that lard contains little or no vitamin A or D. Lot II received 2 ounces of butter; Lot III, 2 ounces of oleomargarine; and Lot IV, 2 ounces of vegetable margarine for each 100 pounds of live weight daily.

Two litters of pigs were employed, one litter being purebred Berkshires and the other being sired by a Berkshire boar and out of a Duroc-Jersey sow. It was necessary to use nine of the cross-breds

and seven purebreds, making three cross-breds and one purebred, in Lot II. The pigs were all of the same age, about ten weeks old when put on feed.

Table 10 gives a summary of the feed and weight records. These pigs went for a longer period than any previous group before showing any symptoms of avitaminosis. The rate of gains was quite satisfactory in all lots. Table 11 gives individual weights by two-week periods for the 16 pigs. Figure 17 shows the total lot weights of these pigs.

Tables 10 and 11 show that all lots received adequate amounts of energy to make satisfactory gains. As in previous trials, the small

FIGURE 16.—Sections of ribs from a pig affected with rickets. Note the areas of porous bone, the thickening of the rib on the right, and the area of fresh calcification at the end of the bone

number of pigs does not justify any comparison of the value of the rations as measured by gains on pigs or by amounts of feed per unit of gain.

On November 18 the pigs in Lots I and IV began to leave feed in their troughs. They were fed night and morning, but some feed remained in the troughs 4 or 5 hours before being eaten. Lots II and III cleaned up their feed within 15 minutes. On December 1 the pigs in Lot I were in poor condition, had poor appetites, were sluggish, and had dull hair. Pig "3XS" of this lot was in especially bad condition, the eyes being red and watery, in addition to the other symptoms mentioned. On December 8 pig "3XS," Lot I, and pig "1XS," Lot

TABLE 11.—*Individual and Total Lot Weights by Two-week Periods of Pigs in Four Lots in 1937*

Lot	Pig	Weights at Two-week Intervals *(Pounds)*									
		Aug. 11	Aug. 25	Sept. 8	Sept. 22	Oct. 6	Oct. 20	Nov. 3	Nov. 17	Dec. 1	Dec. 15
I	3XS	45	72	64	102	133	150	175	209	225	235
	0BS	34	46	47	56	96	116	148	169	205	218
	10BS	32	40	76	75	72	90	117	151	163	181
	10XS	56	74	90	104	132	154	182	210	217	219
	Total	167	232	277	341	433	510	622	739	810	853
II	1XB	47	59	52	82	94	114	139	158	186	197
	0XB	32	46	61	63	84	109	134	166	200	224
	30XB	49	68	84	105	122	163	194	229	260	279
	30BS	36	53	89	98	103	124	145	178	194	221
	Total	164	226	286	328	403	510	612	731	840	921
III	0XS	45	66	82	96	125	144	167	190	213	232
	90BS	38	44	56	66	84	108	135	162	182	198
	9XB	50	69	87	99	123	150	173	202	230	245
	30BB	33	43	52	62	78	88	133	158	165	193
	Total	166	222	277	323	410	500	608	712	800	868
IV	0BB	38	43	60	70	83	104	130	164	193	217
	3XB	57	78	93	102	123	145	165	196	221	242
	1XB	33	47	65	77	101	123	151	166	177	171
	3BB	38	48	51	64	84	98	130	158	183	200
	Total	166	216	269	313	391	470	576	684	774	830

IV, had badly inflamed eyes, walked with an uncertain, staggering gait in the hind quarters, and were quite nervous. Lots II and III were in good thrifty condition on this date.

The pigs were removed from experiment on December 15. At this time all pigs in Lots I and IV showed inflammation of the eyes and lack of co-ordination in hind quarters, and were very nervous and restless. Pigs "10XS," Lot I, and "1XS," Lot IV, were especially

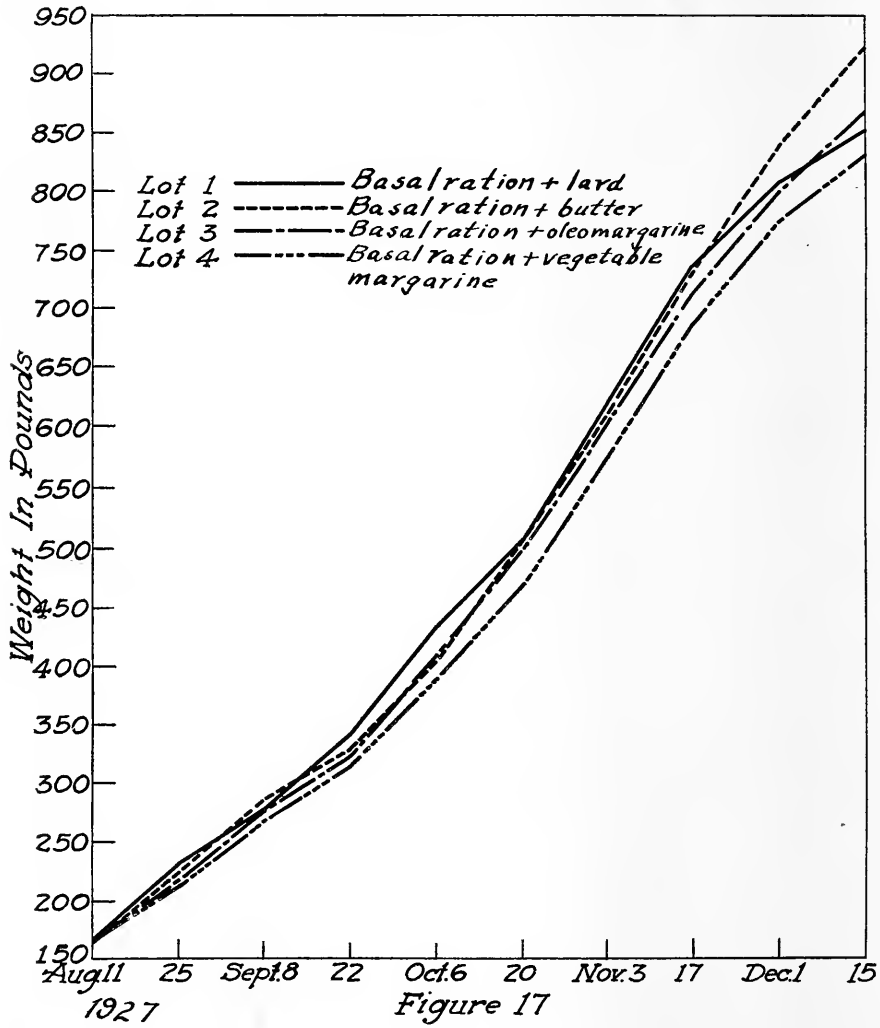


FIGURE 17.—Growth Curves Based on Total Lot Weights as Given in Table 11

As seen in Figure 17, gains were rapid and uniform in all lots until December 1, when Lot I and Lot IV began to go down.

affected. "0BB" and "3BB," Lot IV, were quite restless and affected with short, labored, convulsive breathing. "3BB" had attacks of partial paralysis and at times was unable to rise. All pigs in Lots II and III were thrifty and gaining well.

Immediately after being removed from the experiment each pig in Lots I and IV was given a tablespoonful of oxygenated cod-liver oil, the dose being repeated each morning and evening and the ration being kept the same. On December 18 "3BB," Lot IV, died. All the other pigs showed immediate and marked improvement in co-ordination. The eyes, however, still remained sore, and the pigs suffering from difficult breathing showed no improvement. On December 19 yellow corn was substituted for the white corn of the ration, and untreated cod-liver oil was given. All pigs showed marked improvement and were apparently normal on December 29.

SUMMARY

Four years' work in comparing butter, oleomargarine, and vegetable oil margarine as sources of fat-soluble vitamin for pigs are reported.

In 1923 three lots of pigs received a basal ration of white corn, oats, tankage, and linseed oilmeal. To the ration of Lot II was added one ounce of butter for each 100 pounds of live weight, and to the basal ration of Lot III was added one ounce of oleomargarine for each 100 pounds of live weight. During the feeding period of 98 days the pigs of Lots II and III gained slightly more than Lot I, the check lot, but the difference was not great enough to be considered important.

In 1925 similar results were obtained by feeding the same basal ration, but using vegetable oil margarine in place of oleomargarine in Lot III.

Pigs receiving a ration of white corn, buckwheat middlings, and tankage in the 1926 trial developed rickets, two animals going down on the 86th day. One animal died and was examined. The examination showed a fractured lumbar vertebra, beading of the ribs, and abnormal calcification of the femurs. Oxygenated cod-liver oil brought about recovery. One of the pigs receiving untreated cod-liver oil died. The lot receiving the basal ration plus butter showed no symptoms of rickets during the 126-day feeding period. The check lot, which received white corn, oats, tankage, and linseed oilmeal did not develop rickets.

Four lots of pigs received the known rachitic ration of white corn, buckwheat middlings, and tankage in the 1927 trial. Lot II received 2 ounces of butter per 100 pounds of live weight daily; Lot III, two ounces of oleomargarine; Lot IV, two ounces of vegetable oil margarine; and Lot I, sufficient lard to maintain the energy intake on the

same level as that of the other three lots. Lot I, receiving the lard, and Lot IV, receiving the vegetable oil margarine, developed symptoms of vitamin A and D deficiency in 100 to 110 days. Butter and oleomargarine appeared to be equally effective in preventing the trouble for a period of 126 days.

LITERATURE CITED

HALLIBURTON, W. D., and DRUMMOND, J. C.
1917. THE NUTRITIVE VALUE OF MARGARINE AND BUTTER SUBSTITUTES WITH REFERENCE TO THEIR CONTENT OF THE FAT-SOLUBLE ACCESSORY GROWTH SUBSTANCE. Jour. Physiol. 51, 235.

LIVESAY, E. A., and STILLWELL, E. C.
1926. THE INFLUENCE OF THE ADDITION OF OATS TO A WHITE CORN RATION IN GROWING AND FATTENING PIGS. Proc. Amer. Soc. An. Prod.

———, ———
1927. COMPARATIVE TESTS OF CERTAIN FEEDS IN RATIONS FOR PIGS. W. Va. Exp. Sta. Bul. 213.

MELLANBY, E.
1921. EXPERIMENTAL RICKETS.
Med. Res. Council, London.

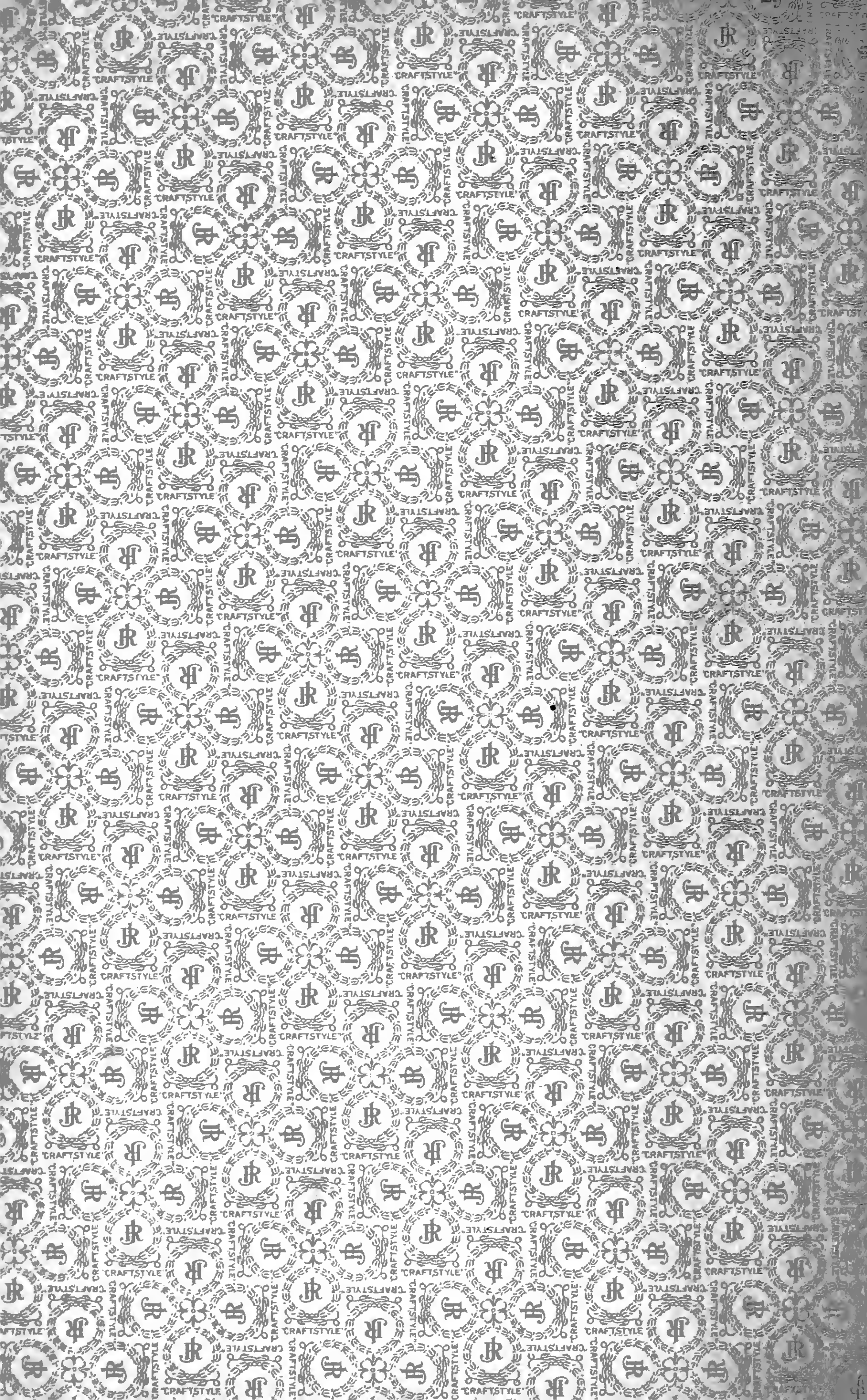
MCCOLLUM, E. V., SIMMONDS, N., SHIPLEY, P. G., and PARK, E. A.
1922. IS THERE A SUBSTANCE OTHER THAN FAT-SOLUBLE A ASSOCIATED WITH CERTAIN FATS, WHICH PLAYS AN IMPORTANT ROLE IN BONE DEVELOPMENT?
Jour. Biol. Chem. 50, 5.

———, ———
1925. THE NEWER KNOWLEDGE OF NUTRITION.
3rd edition, 84.

———, ———
1925. THE NEWER KNOWLEDGE OF NUTRITION.
3rd edition, 405.

OSBORNE, T. B., and MENDEL, L. B.
1915. FURTHER OBSERVATIONS OF THE INFLUENCE OF NATURAL FATS UPON GROWTH.
Jour. Biol. Chem. 20, 379.

STEENBOCK, H., and BOUTWELL, P. W.
1920. THE COMPARATIVE NUTRITIVE VALUE OF WHITE AND YELLOW MAIZE.
Jour. Biol. Chem. 41, 81.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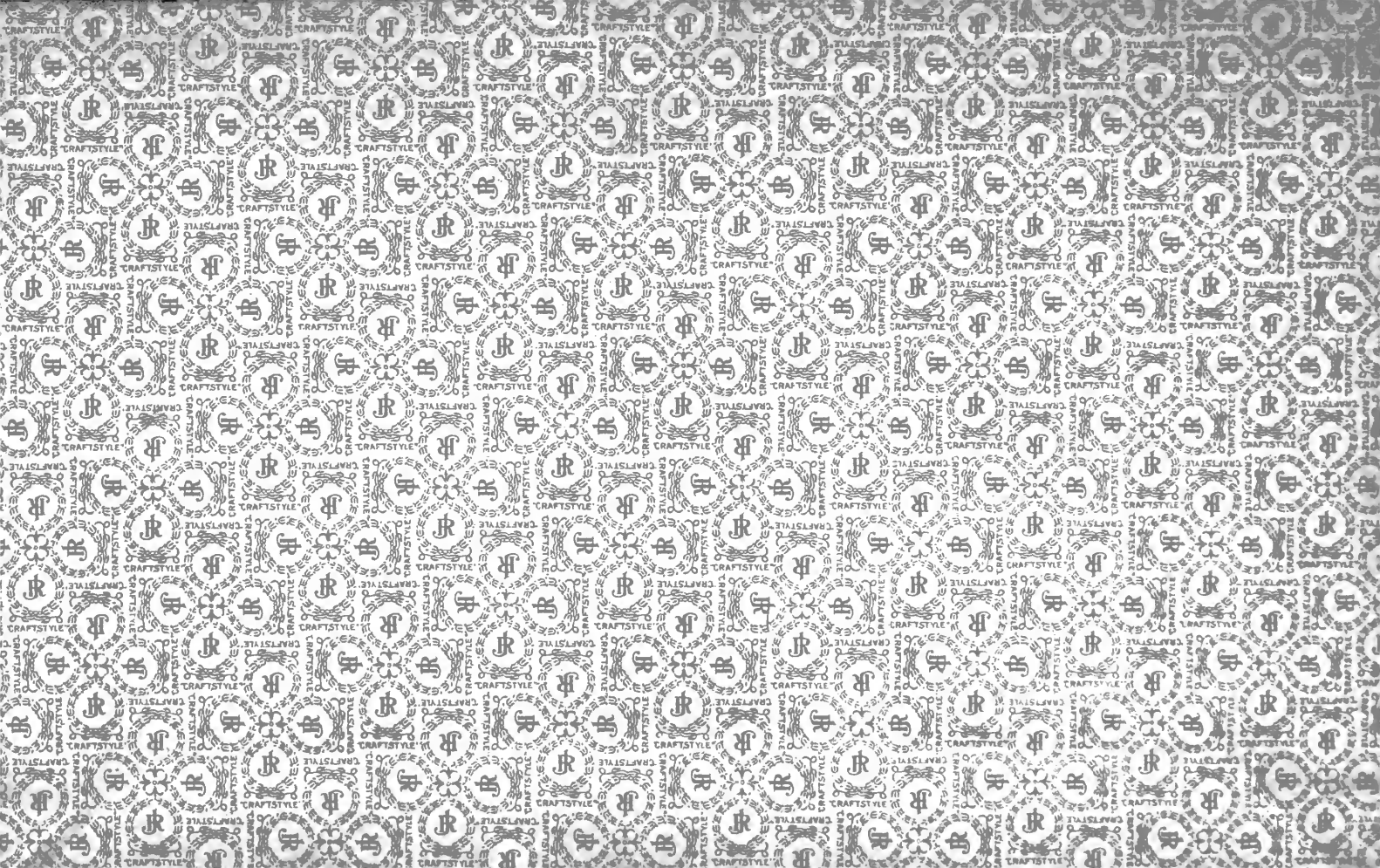
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